INTERFERENCE AND NOISE ESTIMATION IN AN OFDM SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Ser. No. 60/470,724, filed May 14, 2003, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the field of wireless communications. More particularly, the invention relates to systems and methods for estimating noise in an Orthogonal Frequency Division Multiplexing (OFDM) system.

2. Description of the Related Art

Wireless communication systems are continually relied upon to transmit enormous amounts of data in a variety of operating conditions. The amount of frequency spectrum, or bandwidth, that is allocated to a communication system is often limited by government regulations. Thus, there is a constant need to optimize data throughput in a given communication bandwidth.

The problem of optimizing data throughput in a given communication band is compounded by the need to simultaneously support multiple users. The users may each have different communication needs. One user may be transmitting low rate signals, such as voice signals, while another user may be transmitting high rate data signals, such as video. A communication system can implement a particular method of efficiently utilizing a communication band to support multiple users.

Wireless communication systems can be implemented in many different ways. For example, Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Orthogonal Frequency Division Multiplexing (OFDM) are used in wireless communication systems. Each of the different communication systems has advantages and disadvantages related to particular system aspects.

FIG. **1** is a frequency-time representation of signals in a typical OFDM system. The OFDM system has an allocated frequency spectrum **120**. The allocated frequency spectrum **120** is divided into multiple carriers, for example **130***a*-**130***d* and **132***a*-**132***d*. The multiple carriers in an OFDM system may also be referred to as sub-carriers. Each of the sub-carriers, for example **130***a*, is modulated with a low rate data stream. Additionally, as the system name implies, each of the sub-carriers, for example **130***a*, is orthogonal to all of the other sub-carriers, for example **130***b*-**130***d* and **132***a*-**132***d*.

The sub-carriers, for example **130***a*-**130***d*, can be constructed to be orthogonal to one another by gating the sub-carrier on and off. A sub-carrier, for example **130***a*, gated on and off using a rectangular window produces a frequency spectrum having a (sin (x))/x shape. The rectangular gating period and the frequency spacing of the sub-carriers, for example **130***a* and **130***b*, can be chosen such that the spectrum of the modulated first sub-carrier **130***a* is nulled at the center frequencies of the other sub-carriers, for example **130***b*-**130***d*.

The OFDM system can be configured to support multiple users by allocating a portion of the sub-carriers to each user. For example, a first user may be allocated a first set of sub-carriers **130***a*-**130***d* and a second user may be allocated a second set of sub-carriers **132***a*-**132***d*. The number of sub-carriers allocated to users need not be the same and the sub-carriers do not need to be in a contiguous band.

Thus, in the time domain, a number of OFDM symbols **110***a*-**110***n* are transmitted, resulting in a frequency spectrum of orthogonal sub-carriers **130***a*-**130***d* and **132***a*-**132***d*. Each of the sub-carriers, for example **130***a*, is independently modulated. One or more sub-carriers **130***a*-**130***d* may be allocated to an individual communication link. Additionally, the number of sub-carriers assigned to a particular user may change over time.

Thus, OFDM is a promising multiplexing technique for high data rate transmission over wireless channels that can be implemented in wireless communication systems, such as cellular communication systems supporting large numbers of users. However, cellular systems use a frequency reuse concept to enhance the efficiency of spectral utilization. Frequency reuse introduces co-channel interference (CCI), which is a major source of performance degradation in such systems. As discussed above, all users within the same cell or sector of an OFDM system are orthogonal to each other because all of the sub-carriers are orthogonal. Thus, within the same cell or sector, the multiple sub-carriers cause substantially no interference to each other. However, adjacent cells or sectors may use the same frequency space because of frequency reuse. Hence, in an OFDM system, users in different cells or sectors are sources of interference and produce the main source of CCI for adjacent cells or sectors.

It is desirable to be able to determine the level of CCI in an OFDM wireless communication receiver. The level of CCI is needed at the receiver for two main reasons. The receiver may operate in a closed power control loop with a transmitter and needs to know the level of CCI to adjust the power level transmitted on each sub-carrier in order to maintain the signal to interference plus noise ratio (SNIR) required for a certain performance. The receiver also needs an estimate of CCI for Carrier to Interference (C/I) or SINR values that are used in the operation of a channel decoder.

SUMMARY OF THE INVENTION

A method and apparatus for determining a noise estimate in an OFDM system are disclosed. An estimate of the noise can be determined by detecting the received power in an unassigned sub-carrier frequency band. If the unassigned sub-carrier frequency band corresponds to a locally unassigned sub-carrier, the received power represents an estimate of the noise plus interference in the sub-carrier frequency band. If the unassigned sub-carrier frequency band corresponds to a system wide unassigned sub-carrier, the received power represents an estimate of the noise floor in the sub-carrier frequency band.

In one aspect, the invention is a method of determining a noise estimate comprising receiving OFDM symbols and detecting a received power in an unassigned sub-carrier frequency band. In another aspect, the invention is a method of determining a noise estimate comprising receiving OFDM symbols in a wireless cellular communication system, where the symbols correspond to a symbol period. The method includes determining unassigned sub-carriers during the symbol period and determining a received power of signals in the unassigned sub-carrier frequency bands. The power is stored in memory and averaged with previously stored values to generate a noise estimate.

In another aspect, the invention is an apparatus for estimating noise in an OFDM system. The apparatus includes a receiver configured to wirelessly receive OFDM symbols and a detector configured to detect the received power level of